

## Measuring Tropical Forest Sustainability on Islands in the Pacific and Caribbean using the Montreal Process Criteria and Indicators Framework

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### Abstract

We present a comprehensive synthesis of ecological, economic, and social information designed to facilitate the assessment of forest sustainability on islands in the tropics and subtropics of the United States and affiliated jurisdictions. We used the Montréal Process Criteria and Indicators as a basis for gathering and organizing this information. The results represent a first approximation forest sustainability assessment for these islands and serve as a baseline for detecting forest trends. Across the nine jurisdictions, forest area totals about 3 million acres and is relatively stable on most islands, with minor losses occurring in some areas mainly due to pressure from human development. A significant amount of forest is in relatively young stands (re)established on agricultural lands abandoned in the last century, particularly in Hawaii and the Caribbean. Most islands have relatively high levels of biological diversity and numbers of endemic species, some of which are threatened by non-native invasive species. Commercial forestry is limited on, if not absent from, most islands, excepting Hawaii, but linkages between people and forests are very strong as forests provide subsistence foods, medicinal compounds, and other materials for daily and cultural uses. Moreover, fresh water and marine resources are central to the social, cultural, and economic life of the islands and forest cover is critical to maintaining their productivity and resilience. Institutional capacity is limited largely by lack of resources for most islands, but partially offset through regional collaboration and leveraged funds. For certain indicators, particularly those that rely on forest inventory data, there is fairly uniform information across the islands, while for others, such as forest health and socioeconomic indicators, information is mostly island- or topic- specific. Additional findings and implications for future assessments and policy-making also are discussed.

*Keywords: sustainability assessment; tropical forest; island; Pacific; Caribbean*

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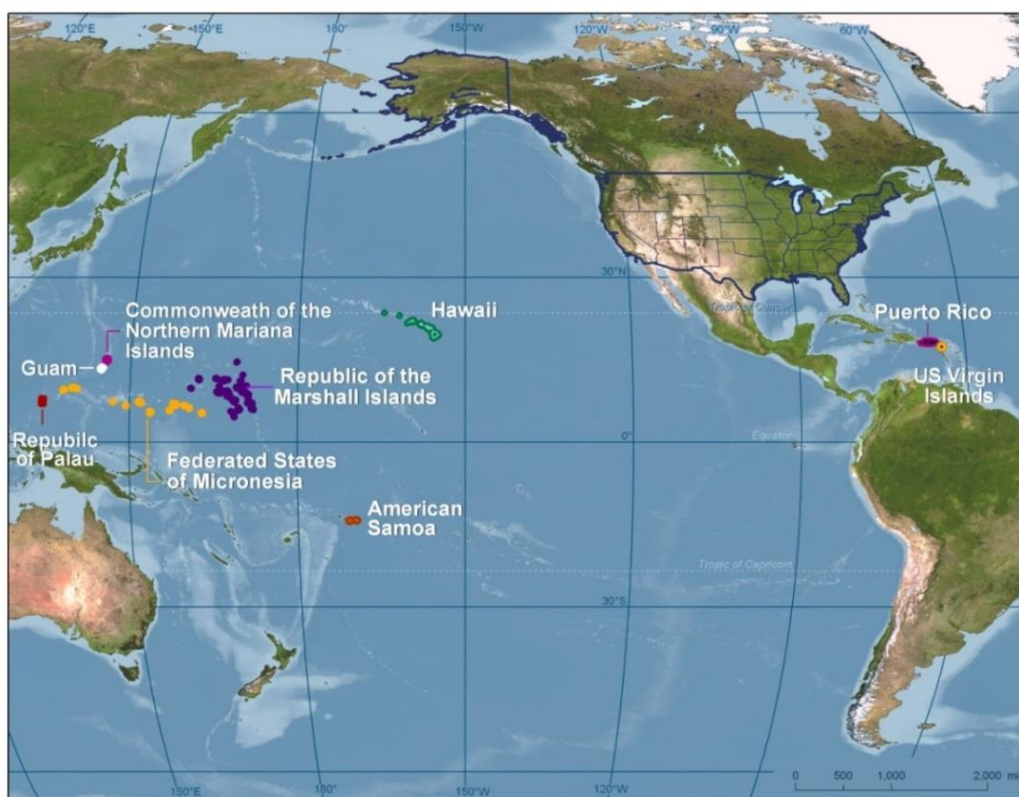
### Introduction

Broadly defined, forest sustainability refers to the ability of forest ecosystems to maintain desired characteristics and provide preferred outputs into the future. Numerous international processes and accords aim to characterize and monitor forest sustainability. Many of these initiatives define and apply frameworks for assessing forest sustainability, for example through broad *criteria* that describe environmental, economic, and social forest values and *indicators* that can be used to measure and track changes in forests and forest related conditions. These frameworks are designed and applied at multiple levels (e.g., national, forest management unit).

The Montréal Process Criteria and Indicators for Forest Conservation and Sustainable Management (MPC&I) provide a framework for gathering and organizing information on forest ecosystem characteristics and related socioeconomic factors to assess forest sustainability at the national level (Montréal Process 2009). Twelve countries, including the United States, voluntarily participate in the Montréal Process through the development and application of these C&I. In this paper, we present current and historical information generated from the application of the MPC&I in the subtropical and tropical islands of the United States and affiliated jurisdictions in the Pacific region. The results provide a first approximation forest sustainability assessment for these islands and are part of a larger U.S. effort to implement the MPC&I beyond the continental U.S. Other C&I that are specifically tailored to tropical forests exist (e.g., International Tropical Timber Organization C&I for the sustainable management of tropical forests (ITTO 2005)), but the vast majority of Montreal Process indicators are equally applicable to temperate and tropical forests.

Nine island jurisdictions are included in this study (Fig.1). They are, from East to West:

- U.S. Territory of the Virgin Islands (Virgin Islands, or USVI)
- Commonwealth of Puerto Rico (Puerto Rico, or PR)
- State of Hawaii (Hawaii, or HI)
- Territory of American Samoa (Am. Samoa, or AS)
- Republic of the Marshall Islands (Marshalls, or RMI)
- Federated States of Micronesia (Micronesia, or FSM)
- Commonwealth of the Northern Mariana Islands (N. Marianas, or CNMI)
- Territory of Guam (Guam, or GU)
- Republic of Palau (Palau, or RP; also called Belau)



**Figure 1. U.S. and Affiliated Island Jurisdictions Assessed Using the Montreal Process Criteria and Indicators for the Conservation and Sustainable Management of Forests (Ramos 2012).**

The geographic heterogeneity of these islands is mirrored in the range in political arrangements from statehood to territories to nations in Compacts of Free Association with the U.S. (Table 1). These differences, in turn are associated with different forest management arrangements and different data reporting conventions. Demographics likewise range from large and highly concentrated urban populations in Puerto Rico and Hawaii (in Honolulu at least), to small and dispersed rural or semi-rural settlements elsewhere in the Pacific. Social and economic conditions also vary considerably across the islands.

**Table 1. US. and Affiliated Island Jurisdiction Key Characteristics**

Island jurisdictions	Total Area (acres)	Political status	Islands		Population (2010)	GDP per capita*
			Permanently inhabited	Other		
Virgin Islands	85,760	Territory with three states: St. Croix, St. John, St. Thomas	4	50 islands & cays	106,405	\$14,500 <sup>a</sup>
Puerto Rico	2,199,901	Commonwealth	3	3+	3,725,789	\$16,300 <sup>d</sup>
Hawaii	4,127,337	State	7	Kahoolawe + 9 Northwestern islands/atolls + 130 small islands	1,360,301	\$44,024 <sup>c</sup>
Am. Samoa	49,280	Territory	5 islands + Swain's Atoll	Rose Atoll	55,519	\$8,000 <sup>b</sup>
Marshalls	44,800	Nation	20 atolls + 4 islands	9 atolls + Jemo Island	67,182	\$8,600 <sup>f</sup>
Micronesia (FSM)	149,804	Nation with four states: Kosrae, Pohnpei, Chuuk (Truk), Yap (Waab)	65 islands & atolls	542 islands & atolls	106,836	\$7,100 <sup>f</sup>
N. Marianas	113,280	Commonwealth	3	12 Northern Islands	53,883	\$13,600 <sup>d</sup>
Guam	135,680	Territory	1		159,358	\$28,700 <sup>d</sup>
Palau	114,560	Nation with 16 states	7 islands + Kayangel Atoll	250 including "Rock Islands"	20,956	\$10,500 <sup>e</sup>

Sources: U.S. Census <http://www.census.gov/>; CIA World Factbook

<https://www.cia.gov/library/publications/the-world-factbook/>

\*a = 2004, b = 2007, c = 2009, d = 2010, e = 2011, f = 2013

## Measurement Approach

The MPC&I encompass 54 indicators arranged under 7 criteria that address the biophysical (C1-5), socioeconomic (C6) and legal, policy, and institutional (C7) characteristics of forests. The first five criteria rely heavily on data generated by forest inventory and monitoring activities, particularly in regard to the biophysical characteristics of these island forest systems. The USDA Forest Service's Forest Inventory and Analysis (FIA) program provides much of this type of information for these islands. Other data collection efforts and standalone studies provide information on forest species, forest health (e.g. invasive species and forest disturbance processes), and the extent and nature of forest cover.

The sixth criterion relies primarily on social and economic statistics generated outside of the forest sector. In this domain, major reporting mechanisms such as the U.S. Census and the Department of Commerce provide data that is well outside the scope of the U.S. Forest Service or local forest agencies, but which is nonetheless essential to understanding the social and economic dimensions of forest sustainability in the islands. A number of other sources provide various quantitative and qualitative information on socioeconomic forest conditions and trends. The last Criterion uses mainly qualitative, standalone or site-specific data sources to describe forest laws, policies, and institutions.

When possible, we report on trends in recent years (2003-2010), as well as changes from reference conditions. However, time series data adequate to measure changes in forest area (for example) are not available for most of these islands, and are mostly non-existent for other indicators. Overall, there is a fairly broad range of data available for measuring and reporting on the MPC&I for these islands, but disproportionately more information exists related to key biophysical aspects than economic or social aspects. Also, there is considerable variation in data availability, forms, quality, and collection frequency, associated in part with political status, location, topography, and local economy.

## **Results and Discussion**

In the following sections, we present and discuss some of the key findings related to each criterion of the Montreal Process framework.

### **Criterion 1 Biological Diversity**

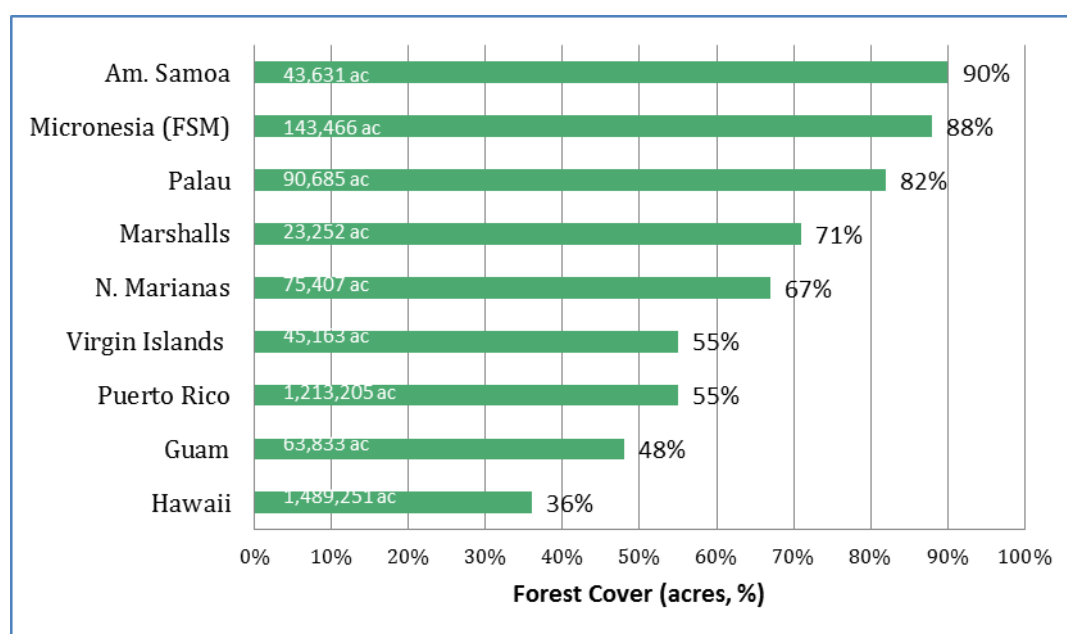
There are approximately 3 million acres of forest across the island jurisdictions considered in this study, ranging from nearly 1.5 million acres in Hawaii to less than 25,000 acres in the Marshall Islands. Much of this forested land, particularly in Hawaii and the Caribbean, is comprised of relatively young stands established on agricultural lands abandoned in the last century. The percentage of total land area in forest ranges from 90% in American Samoa to 36% in Hawaii (pre-settlement percentages can be assumed to approach 100% except in Hawaii where high elevations and volcanic landscapes preclude forest cover).

Total acreage of forest land appears to be relatively stable across these islands, but this fact masks local and regional shifts in forest area and type. Most inhabited islands have experienced forest recovery following the abandonment of agricultural lands that were converted from forests in the early 1900s. Forest lost to agriculture generally has been much higher than loss to development, though recent figures show forests are under increasing pressure from urban and tourism land use changes. For example, in Puerto Rico, where forests were nearly completely lost to agriculture by the early 1900s, forests have recovered to cover about 55 percent of the island. Forest colonization of abandoned lands in Puerto Rico still compensates for loss to development, but development pressures are leading to locally significant fragmentation and loss of forested lands.

Formal forest protection rates vary significantly among these island jurisdictions, with little formally protected forest in Guam, and up to 43 percent of forests formally protected in Hawaii. In addition to formal forest protection, traditional governance structures have resulted in widespread community forest management and protection, particularly on the Pacific islands.

The forests on these islands are highly diverse compared to most temperate and boreal forests, though not as diverse in plant or animal species richness per unit area as most mainland tropical areas. Nevertheless, most of these islands have high rates of endemism, which correlates with their isolation, climate, and heterogeneity of habitats. Hawaii, in particular, has an exceptionally high ratio of endemic species, including more than 99% of terrestrial insects, spiders, and land snails; 90% of

plants; and more than 80% of breeding birds listed. Concomitantly, extinction rates of forest species are generally much higher than continental rates, in part because island species typically have small populations, restricted genetic diversity, and narrow geographic ranges. More than 300 plant and animal species across the islands are considered at risk of extinction by the International Union for the Conservation of Nature.



**Figure 2. Forest Area and Percent Forest Cover by Island Jurisdiction. (Sources: Brandeis and Turner 2013a, b; Donnegan *et al.* 2004a,b, 2007, 2011a,b,c; Tosi *et al.* 2002)**

## Criterion 2 Productive Capacity

Many island communities depend on forests directly or indirectly for a wide range of extractive and non-extractive goods and services. Some of these goods and services are essential for human survival; others are important to an enhanced quality of life. Island forests are perhaps most valued for water and soil conservation, cultural and spiritual values, recreation, and non-commercial forest products, such as fuelwood, canoe and construction resources, arts and crafts materials, and wild game. There is very little commercial harvest of natural or planted forests on any of the islands, with the exception of Hawaii, where there is an established but small (and growing) timber industry and a discernible area of active forest plantations (~ 6% of total forest area).

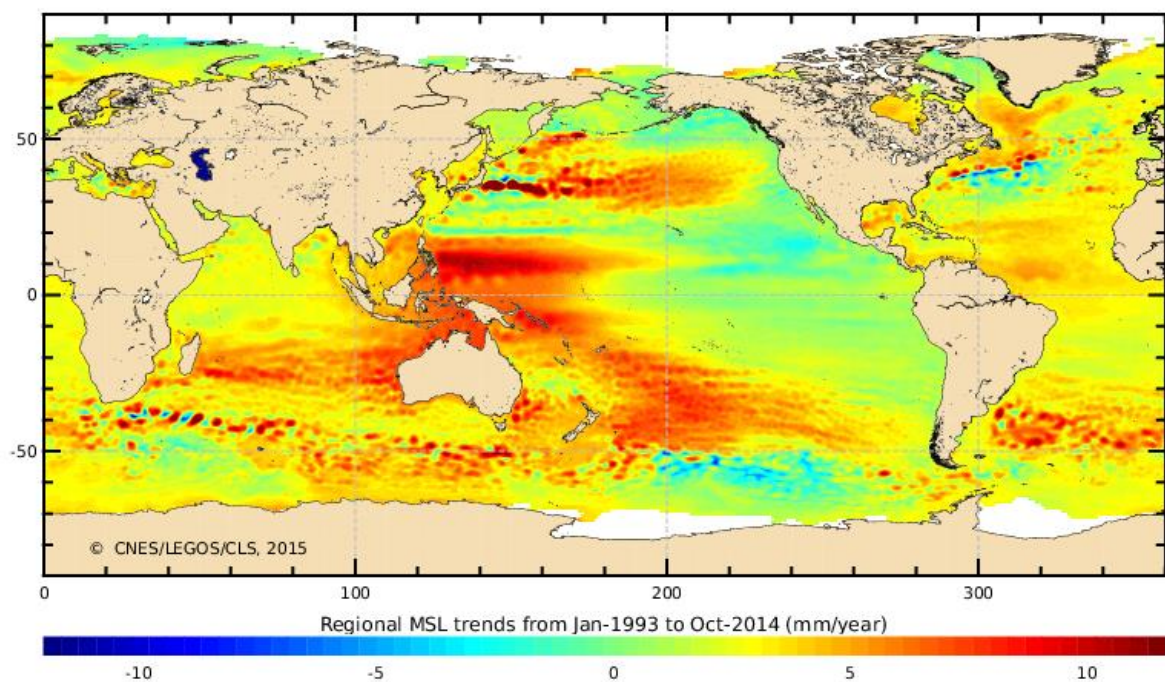
Forests across most of the jurisdictions have fairly high growth rates, but many stands are dominated by relatively young trees (<25 years) of small diameters (< 5 inches dbh) that reflect, in part, land use histories and stages of forest recovery. Much of the wood in these forests is not suitable at present for solid wood products but may be so in the future depending on stocking and growth rates, and applied management and conservation practices. Forest growth appears to be outpacing timber and non-timber forest product harvests in most cases, though some select forest resources in Hawaii (e.g., *Acacia koa* and *Santalum spp.* from natural forest stands outside protected areas) and in the Federated States of Micronesia (e.g., fuelwood from mangrove forests) may be declining.



### Criterion 3 Forest Health and Vitality

Given the isolation and relatively small size of these islands and their land use histories, many are susceptible to disturbances beyond the natural range of variation. For example, animal and plant invasive species may precipitate the loss of endemic species through predation and competition respectively, or can radically alter the structure and function and fire regime of island forests. The islands and regions studied differ in the degree to which their native ecosystems have been affected by invasive species. Hawaiian forests, in particular, have proven highly susceptible to invasions and alteration, partly owing to numerous native plant species being poorly adapted to high levels of competition and herbivory. The resulting loss of unique biodiversity through the extinction of endemic species is well-documented in Hawaii, and is found to be occurring (albeit to lesser degrees) on other islands. For example, the Marianas have been heavily affected by nonnative, invasive species due in part to the activities and effects of war (disturbance) and centuries of interaction with America and Asia (with attendant species introductions). Conversely, although nonnative species have been introduced and some have become widespread in the Caribbean, they have not led to known species losses or other significant impacts, except where introduced grasses replace forests due to repeated human caused fires.

Abiotic agents (e.g., fire, storms, sea level) affecting forests are strongly influenced by climate, whether regional or locally driven by orographic rainfall patterns (Fig. 3). Fire is of increasing concern to forests in the western Pacific, which has a distinct dry season, and to forests in dry areas of Hawaii and the Caribbean. Storms, tsunamis, and hurricanes vary in frequency, but may profoundly affect any island. Tsunami effects during the 2003-2010 period were limited to American Samoa, where a 2009 earthquake and tsunami resulted in significant damage and loss of life. Climate change also affects island forests through changes in temperature and precipitation patterns, with inferred current effects on some forest amphibian populations for example and eventual projected impacts to forested lands due to rising sea levels.



**Figure 3. Regional Mean Sea Levels Trends from January 1993 to October 2014 in mm/yr (CNES/LEGOS/CLS 2015)**

## **Criterion 4 Forest Soil and Water Resources**

In terms of soil resources, while forests cover large areas of most islands, a significant portion of the total forest area has regenerated on lands previously used for agriculture and/or livestock grazing. As a result, most secondary forests occur on compacted, eroded, and otherwise degraded soils.

Nonetheless, these secondary forests contribute greatly to the recuperation, maintenance, and protection of the islands' soil resources. In some cases, the quality of forest soils is threatened by conversion to non-forest uses and by the introduction and spread of feral ungulates that destroy forest vegetation, expose forest soils, and disperse non-native invasive plant species, particularly in Hawaii and many Pacific islands.

Regarding fresh water resources, island forests and their use influence the quantity, quality, and supply of water for growing populations across most jurisdictions, while human water consumption and other activities impact forest water resources and overall forest health. As with soil resources, the conversion of forest lands to other uses has significantly affected water availability and quality on most inhabited islands. In many cases, non-forest land uses such as agriculture and industrial and urban development have led to the over-utilization of existing water supplies, stream diversions, sedimentation of water reservoirs for public consumption, and contamination of surface and ground waters, even affecting estuarine systems. And, while forested areas protect water resources within the watershed and downstream, their protective functions may be increasingly impacted by feral ungulates, fire, non-native species invasions, and unsustainable water withdrawals and diversions. Overall, there is very limited quantitative data on the status or sustainability of the islands' forest soil and water resources, yet the role of healthy forests in maintaining water supply and quality and conserving soil resources is well documented.

## **Criterion 5 Carbon Cycles**

Carbon stock estimates for the different islands vary considerably by size of the island, local conditions, carbon pools studied, and methodology. Compared to continental forests, total island carbon stocks are small, although some stocks are large per unit area, such as soil carbon in wetland peat. Total island carbon stocks range from 0.5 Tg<sup>10</sup> C in the Virgin Islands to over 50 Tg<sup>10</sup> C in Hawaii (Asner *et al.* 2011; Brandeis *et al.* 2007; Brandeis and Oswalt 2007; Donnegan 2005; Donnegan 2010; Donnegan and Holm 2010). Most islands have focused their efforts on managing the effects of climate change through adaptation, with comparatively little focus on mitigation activities, except where per-acre fluxes are potentially large and where there are opportunities for sequestration incentives and bioenergy generation, such as in Hawaii.

## **Criterion 6 Socioeconomic Benefits**

Commercial forestry is quite limited in these islands, with the exception of Hawaii, but socioeconomic linkages between people and forests are nonetheless very strong. The islands also have long-standing cultural ties to and traditions around forests. Owing to the importance of traditional lifestyles for many inhabitants, including subsistence activities, on many islands local residents rely on their forest resources for subsistence foods, medicinal compounds, wood for local crafts and for construction, and other materials for cultural purposes and daily use.

Small and isolated island ecologies reinforce the linkages between forests, agriculture, and coastal fisheries. Traditional economies and subsistence activity make use of the total ecosystem, including forests, and tourism relies on the unique beauty that intact island ecosystems (including forests) provide. The tourism industry is robust on most of the islands, and at least partially linked to forests and the goods and services that they provide. Together, the islands received more than 12.9 million

visitors in 2008, down some from 13.8 million visitors in 2005 (World Trade Organization 2015). However, other related statistics are mostly cursory at best and the actual role of forests in the tourism industry is difficult to parse.

## **Criterion 7 Forest Laws, Policies, and Institutions**

The geographic and ecological heterogeneity that characterizes the islands is paralleled by the heterogeneity of their legal, policy, and institutional arrangements. Land tenure, traditional customs and socioeconomic conditions fundamentally shape which laws and policies are viable. History has left each island with a different political status and unique legal structures. Some type of forest regulation is in place in most islands, but enforcement is uneven given limited institutional capacity and variable degrees of acceptance under various forms of land tenure. Public education and extension are considered essential. With the exception of Hawaii and Puerto Rico, total populations and economies are relatively small (Table 1), and institutions, like many businesses, are subject to economies of scale, such that many islands have limited institutional support for forestry. Most islands partially compensate for these limitations through regional collaboration and leveraging available federal funds and programs. USDA Forest Service assistance to public forest management agencies, and Land Grant extension programs, are present in all jurisdictions.

## **Conclusions**

Through an application of the MPC&I, we have reported on key biophysical characteristics such as forest extent and composition, biological and physical disturbance processes, prevalent social and economic conditions pertaining to forests, and the institutions through which people seek to successfully manage their forest resources in the tropical and subtropical islands of the United States and affiliated jurisdictions in the Pacific region. Overall, forest area appears to be relatively stable and protects key water and soil resources, yet local losses and degradation are not uncommon; forests are diverse but endemic species in particular are susceptible to disturbances outside the natural range of variation; and island communities have deep and complex relationships with and dependencies on forests for food, fiber, fuel, and other goods, though commercial forestry is mainly limited to Hawaii.

Compiling and analyzing information from disparate island jurisdictions separated by vast distances and exhibiting different conditions and histories is no easy task. Much of the information required for complete and comprehensive forest sustainability reporting is not available for these island jurisdictions. Noted data gaps for many jurisdictions include basic forestry information such as the distribution of native, rare, and invasive forest species or water use and withdrawals from forested watersheds. Socioeconomic and institutional information is sparse and mostly anecdotal.

These gaps and weaknesses notwithstanding, there are a number of promising developments in terms of forest sustainability reporting in these islands, including institutionalization of USFS FIA activities that are being augmented by new remote sensing mapping techniques and increased emphasis on monitoring key social and economic dimensions of island forests at local to global levels. Ultimately, island inhabitants rely on forests for a broad range of services and outputs, few of which enter into formal markets or are subject to quantified measurement. To the extent possible, forest reporting and planning exercises need to explicitly identify these outputs and their relative importance, and then incorporate this information in management and monitoring actions.



## Acknowledgements

This paper summarizes key findings from a comprehensive assessment of information about forests on the U.S. tropical islands and affiliated jurisdictions, which relies on a great deal of substantive work related to particular regions and/or subject matter. Some of this is reflected in the references here and in the larger assessment report, yet there were considerable contributions to this project that we would like to acknowledge, including those by Karen Bennett, Leo Zhangfeng-Liu, Lisa Fischer, Thomas Brandeis, Eileen Helmer, Olaf Kueglar, and Olga Ramos. We also are grateful to David Bakke, Donna Ball, Sandra Brown, Jack Ewel, Katherine Ewel, Joseph Donnegan, James Friday, Edgardo Gonzalez, Tamara Heartsill Scalley, William Hollyer, Tracy Johnson, Ariel Lugo, Richard MacKenzie, John Parrotta, Robert Pattison, Pedro Rios, Alicia Takesey, Frank Wadsworth, and Christopher Woodall for their invaluable edits, comments, and suggestions on the larger assessment report.

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